Changes from SRR (June 2002)

- **Contract awarded March 22, 2005 for the Design, Development, and Fabrication of GMI to:**

  Ball Aerospace and Technologies Corporation (BATC)

- **Contract provides for one GMI and an option for a second**

- **High Frequency Channels added subsequent to contract award:**
  - 165.5 GHz (2 channels: V, H polarization)
  - 183.31 GHz (2 channels: ± 3 GHz, ± 9 GHz, V polarization)

The GMI Level-3 Specifications were formulated over a three-year period based upon:

- ***GPM GMI Level 2 Requirements***
- ***Discussions and recommendations obtained from the GPM Project Scientist***
- ***Discussions with the Precipitation Measurement Mission Science Team (PMM)***
- ***GPM Science Workshops***
  - *NASA Workshop on GPM Core Satellite Radiometer Improvements, 8/ 30-31/01*
  - *Algorithm Workshop for Global Precipitation Measurement, March 12, 2002*
- ***Experience with the Tropical Rainfall Measuring Mission TRMM Microwave Imager (TMI)***
  - *Satisfaction of TRMM Scientists with the measurements obtained from TMI*
  - *TMI Instrument Design Specifications*
- ***Instrument Concept and Risk Reduction Studies (ICRR)***
  - *Careful review of GMI Requirements by three industry radiometer vendors*

GMI design supports GPM Mission Science Objectives

- **Measurements**
  - *Light rain and snow, to heavy rainfall over oceans and land, from tropics to arctic*
  - *Improved ground spatial resolution over TMI and other conical scanners*

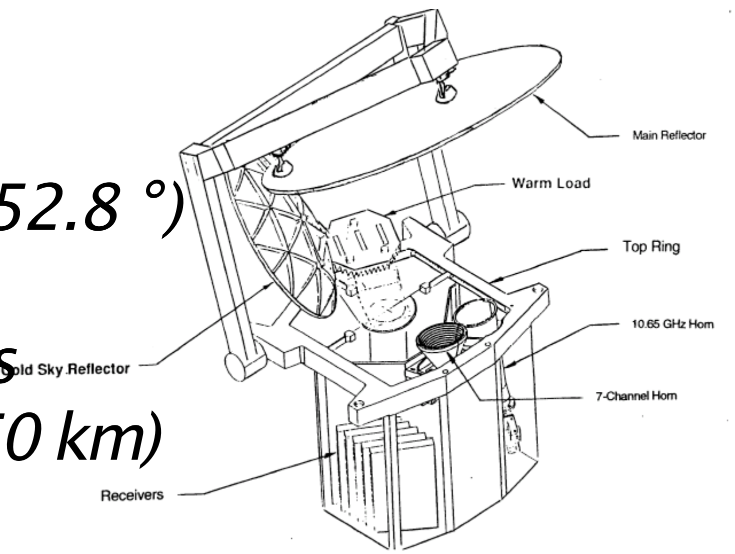
- **Coverage**
  - *Measurement swath enables:*
    - *Contiguous coverage for lower-frequency channels*
    - *≥ 50% coverage for higher frequency channels*
    - *3-hour revisit time for constellation of GPM radiometers*

- **Accuracy**
  - *Well-calibrated and stable receivers minimize error contribution to retrievals*

Instrument Definition: TMI Heritage

GMI builds upon strengths of TMI

- **Maintains Similar Measurement Channels (10 -- 89 GHz)**
- **Conical scan design provides:**
  - Constant Earth Incidence Angle (52.8 °)
  - Resolution and polarization unchanged for all scan positions
  - Broad measurement swath (≥ 850 km)
- **Hot and Cold Calibration every scan**
- **Incorporates mature, low risk, technology**



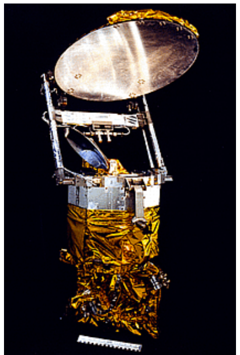
TMI

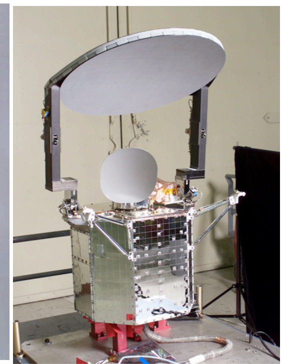
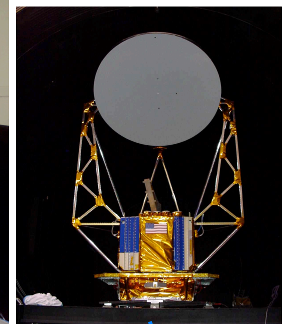
Added features in GMI design: Enhancements from TMI

- **Increased Reflector Aperture Diameter**
  - Diameter doubled to 1.22 m, providing a four-fold improvement in spatial resolution of measurement footprint
    - Full aperture used for channels 1-5, others under-illuminated
    - Reduced uncertainties associated with partial precipitation beam-filling
    - Better sampling strategy (>1.4/IFOV for some lower Chs.)

- **High Frequency Channels (165.5 & 183.3 GHz)**
  - New set of measurement channels not present on TMI
  - Anticipate a new scientific capability to detect light rain and snow; this is
    - Especially important due to higher latitudes at which GPM Core will be making measurements

Instrument Definition: Conical Scanning Radiometers



Inst. / Par.	SSM/I (DMSP)	TMI (TRMM)	AMSR-E (AQUA)	SSMIS (DMSP)	WindSat (Coriolis)	CMIS (NPOESS)	GMI (GPM)
Channels	7	9	12	24	22	61	13
Freq. Cov. (GHz)	19.35 – 85.5	10.65 – 85.5	6.93 – 89.0	19.35 – 183.3	6.8 – 37	6.63 –183.3	10.65 – 183.3
Mass (kg)	48	54	324	96	307	250	125
Power (W)	45	50	350	135	295	340	155
Data Rate (kbps)	3.3	8.8	87.4	13.7	200	300	35
Antenna Diam. (m)	0.61	0.61	1.6	0.61	1.8	2.2	1.22

G L O B A L   P R E C I P I T A T I O N   M E A S U R E M E N T

Requirements and Design Incorporate Lessons from

Other Radiometer Instruments

Use of Protected Measurement Channels

- *Measurement channels adjusted from TMI to conform to NTIA allocations for Earth-remote sensing*

- ***Careful Attention to Calibration***

  Instrument design features addresses calibration problems encountered on:

  - *TMI (Probable de-lamination of VDA coating on main reflector)—Deep Space Cal planned for GMI*
  - *WindSat (Solar heating of hot-load elements)*
  - *AMSR-E (Uncertainty of temperature gradients in hot load)*
  - *GMI has thermally stable warm-load, and 4-point cal*

4.2.6 GMI Contiguous Coverage for Channels 1 through 7

The GMI shall be designed such that its viewing parameters (i.e. the instantaneous field-of-view (IFOV), the earth incidence angle, and the scan rate) will provide contiguous spatial scene coverage from a altitude of 407 km for Channels 1 through 7. Contiguous coverage means that adjacent IFOV footprints, both scan-to-scan and within a scan, show positive overlap

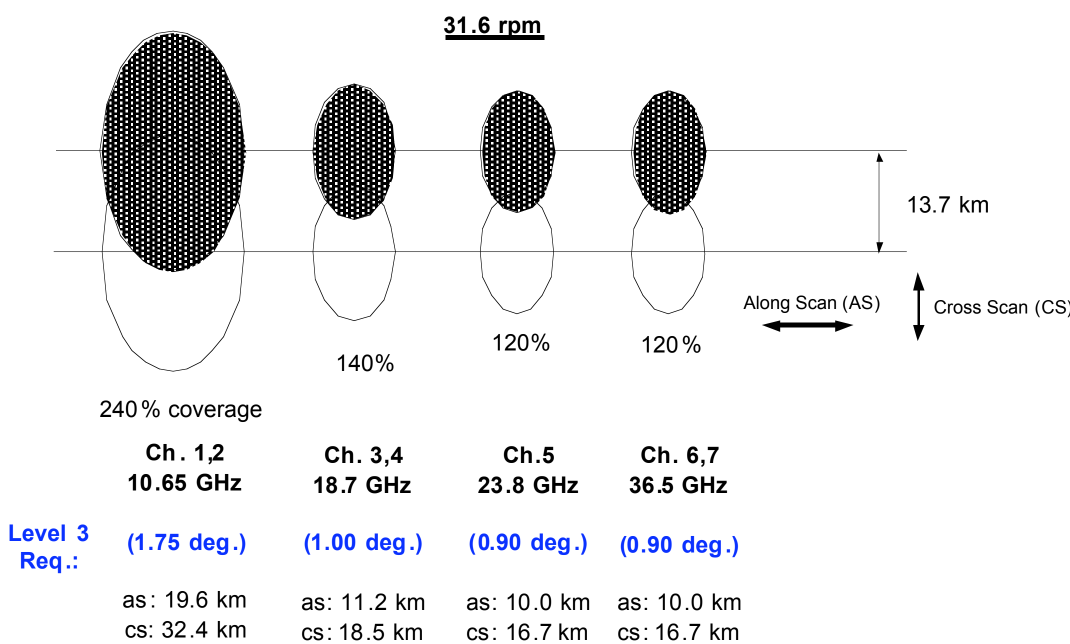
GMI Level 3 Requirement:

Antenna 3dB Beamwidth

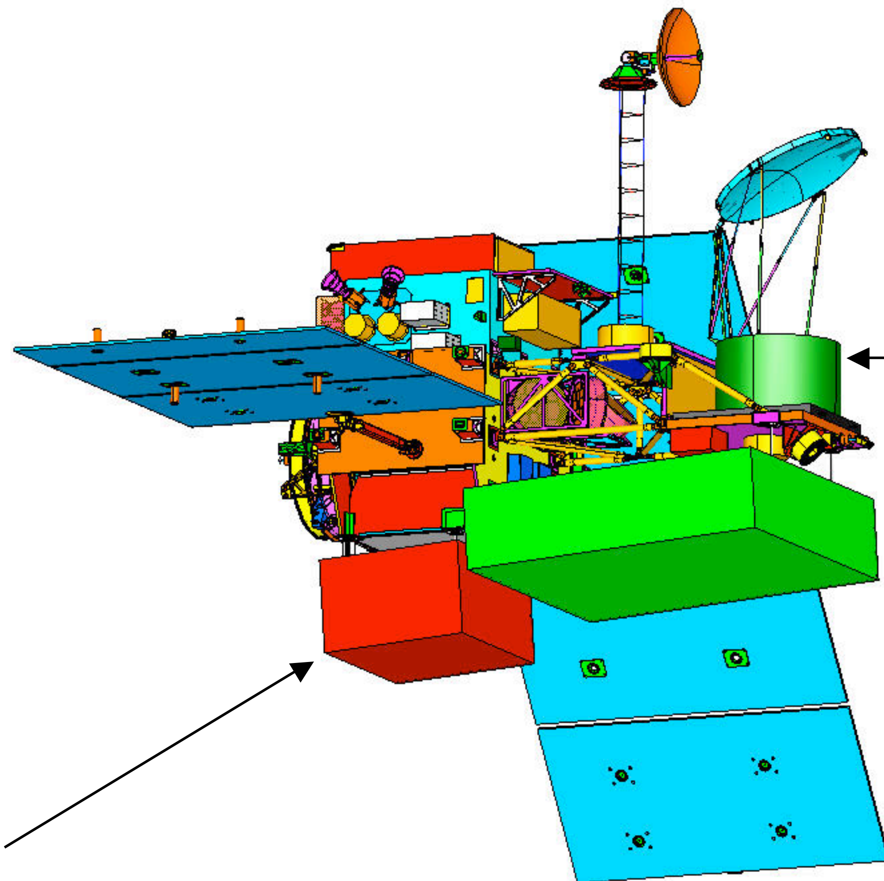
Table 3-1: GMI Channel Set

Channel #	Antenna 3 dB beam width [degrees] (Max.)
1	1.75
2	1.75
3	1.00
4	1.00
5	0.90
6	0.90
7	0.90

GMI Coverage Calculations
IFOVs from Requirements Document Beamwidths
Core Spacecraft
407 km Altitude, Ground Speed = 7.21 km/s



GMI and DRP relative position on GPM core (notional)



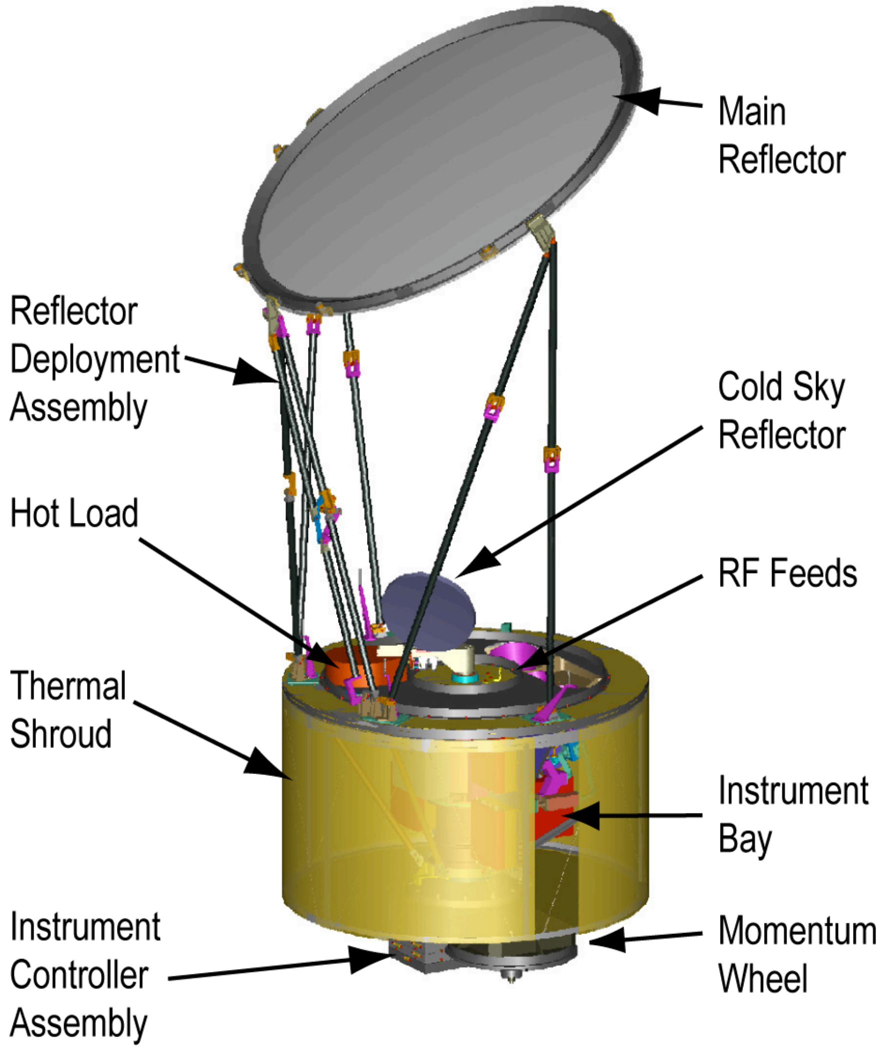
GPM Table 1, GMI vs TMI comparison

CH #	1,2	3,4	5	6,7	8,9	10-13
F(c), (GHz)	10.65 [1] 10.65 [2]	18.7 19.35	23.80 21.30	36.50 37.00	89.00 85.50	165.5-183.31 (+/-)A,B[4]
BW (MHz)	100 100	200 500	200 200	1000 2000	6000 3000	
Int. ti (ms)	9.7 29.6	5.3 14.8	5.0 14.8	2.2 7.4	2.2 3.7	2.2
NEdT (K)(per beam)	0.60 0.55 (0.97)	0.70 0.78 (2.06) [3]	0.90 0.89 (1.53)	0.55 0.77 (1.32)	0.70 1.12 (1.02)	1.9
IFOV (km)[2]	19.6 x 32.4	11.2 x 18.5	10.0 x 16.7	10.7 x 16.7	4.4 x 7.3	4.4 x 7.3
	38.3 x 63.2	18.4 x 30.4	15.5 x 22.6	9.7 x 16.0	4.4 x 7.2	

Remarks: 1. nn.n=GMI, 2. nn.n=TMI, 3. (nn.n)=TMI scaled to GMI, 4. A= 3, B=9

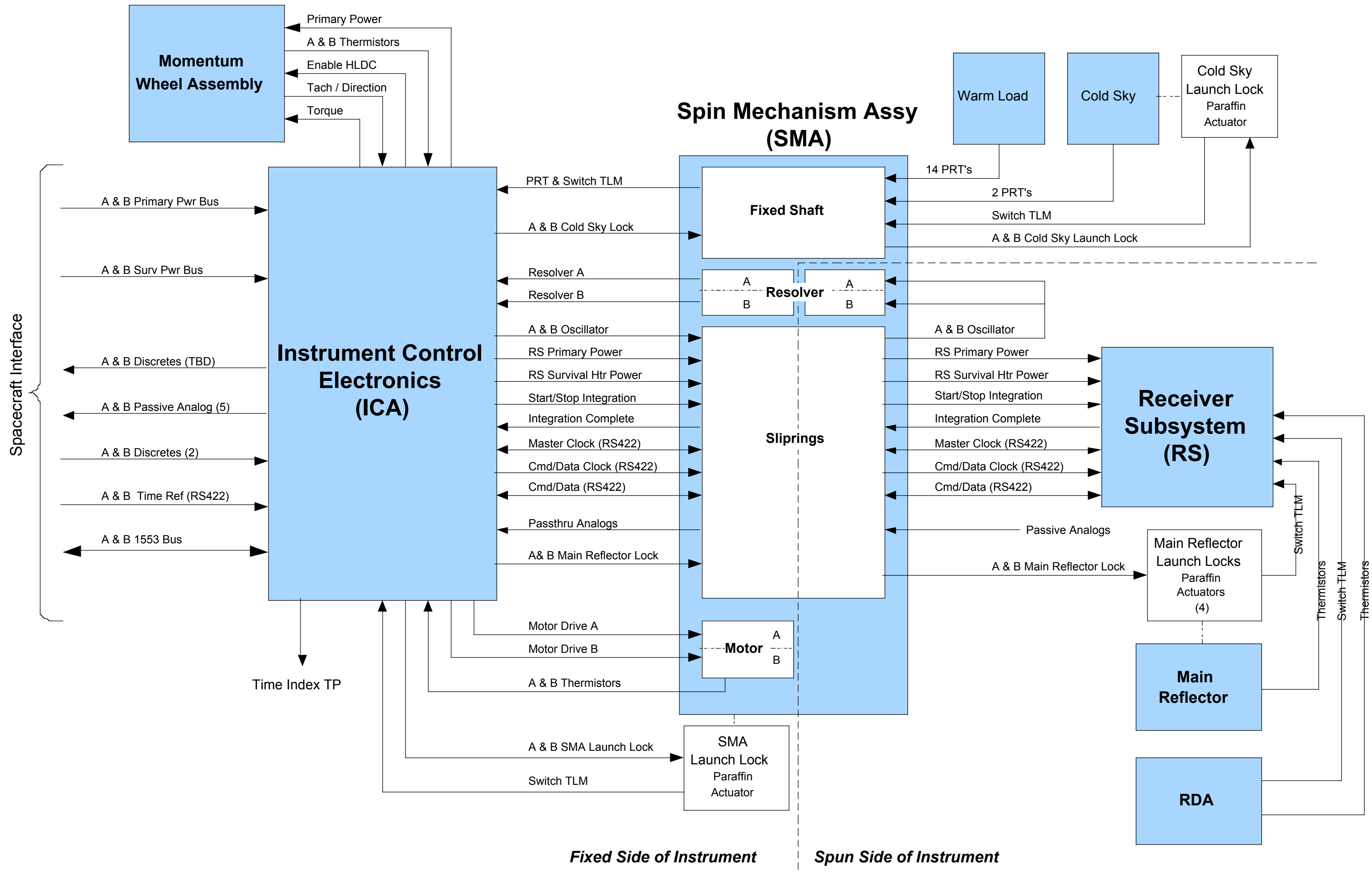
BATC Design
for
GPM Microwave Imager

GMI Design: BATC Design

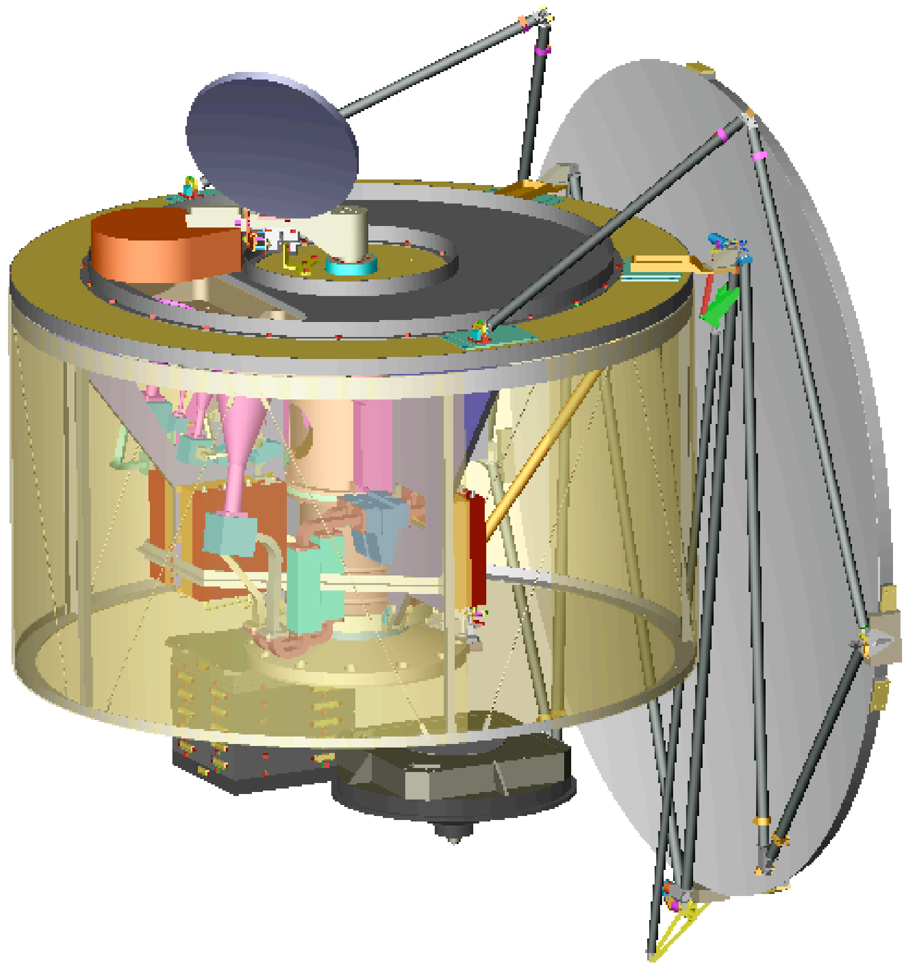


GPM Microwave Imager (BATC)

GMI Design: Electrical Subsystems

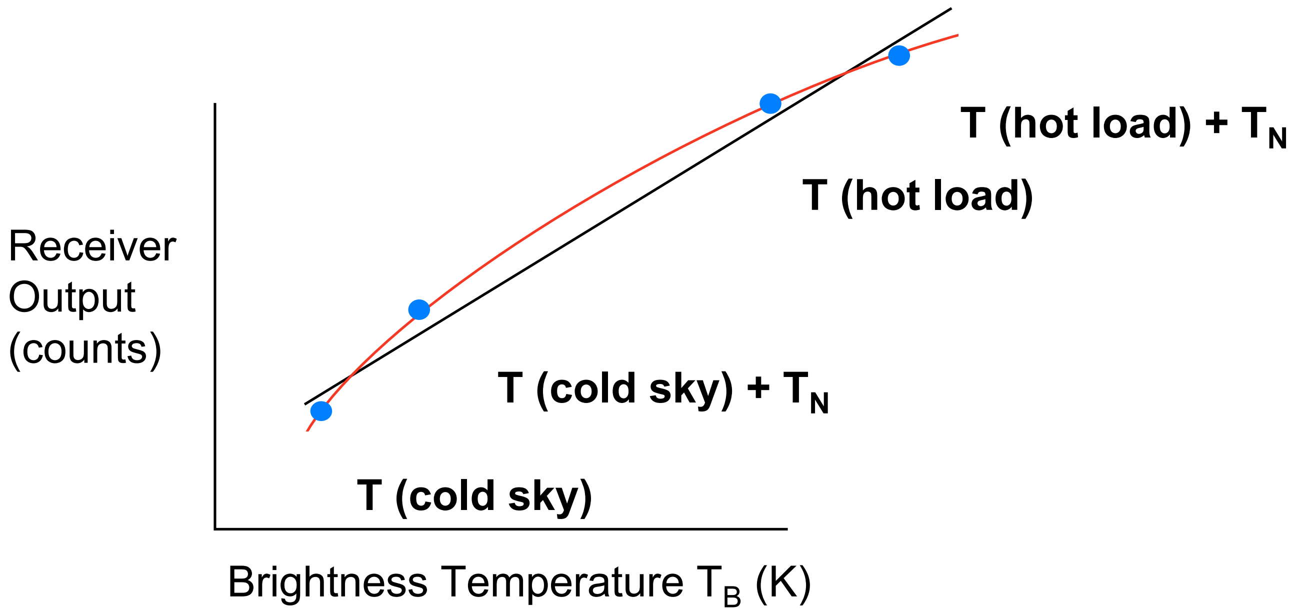


GMI Design: Antenna Stowage / Deployment



On-orbit Measurement Uncertainty will not exceed 1.35 K for Baseline Channels 10 – 89 GHz

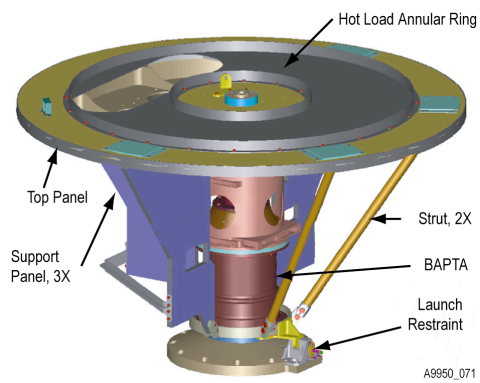
- *GMI calibration design incorporates a "Four-point Calibration Technique" for improved characterization of receiver nonlinearity. Technique employs switchable noise diodes in receiver front-end*



Calibration Load Thermal Isolation

- *A metallic annular ring on top deck thermally isolates hot load from the instrument and from solar impingement. This design reduces thermal gradients in the hot load*

Hot Load Annular Ring



Risk

Risk Title

H-16 DPR/GMI Interference

H-17 GMI Cold Calibration Field of View

H-18 GMI Spin Drive Mechanism

H-19 DPR RFI GMI's 36.5 GHz

H-20 GMI Power Margin

H-21 GMI Gunn Diode Oscillators

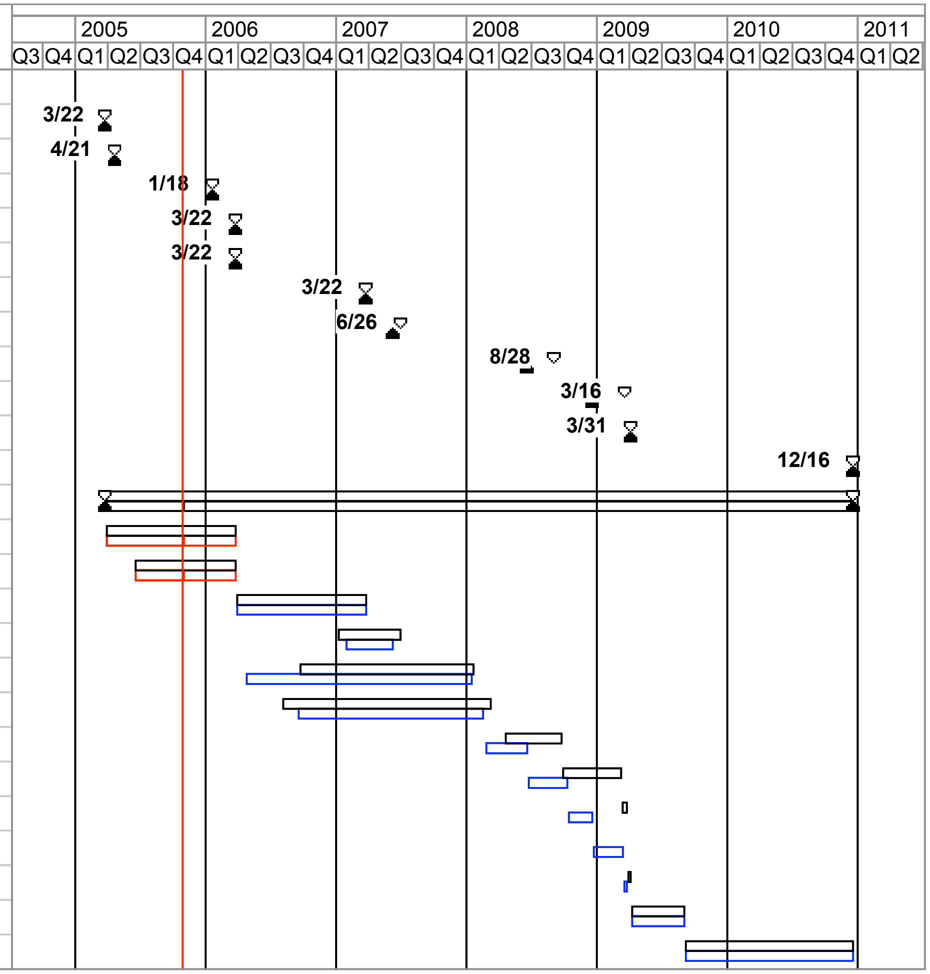
H-22 GMI Cost Growth

		Impact				
		1	2	3	4	5
Probability	5					
	4					
	3		H-19	H-20 H-22		
	2				H-17 H-21	H-16 H-18
	1					

GMI Procurement Status

Detailed GMI Schedule

ID	Task Name	Start	Finish
1	**GMI Milestones\Reviews**	**3/22/05**	**12/16/10**
2	GMI Contract Award	3/22/05	3/22/05
3	Program Kick-Off	4/21/05	4/21/05
4	Integrated Baseline Review (IBR)	1/18/06	1/18/06
5	Preliminary Design Review (PDR)	3/22/06	3/22/06
6	2nd Instrument Option Deadline	3/22/06	3/22/06
7	Critical Design Review (CDR)	3/22/07	3/22/07
8	EMU Verifications Complete	6/5/07	6/5/07
9	Flight 1 Pre-Environmental Review (PER)	6/16/08	6/16/08
10	Flight 1 Pre-Ship Review (PSR)	12/15/08	12/15/08
11	GMI Delivery to GSFC	3/31/09	3/31/09
12	GPM Launch	12/16/10	12/16/10
13	**BATC Instrument Activities**	**3/22/05**	**12/14/10**
14	Systems Analyses	3/22/05	3/22/06
15	Preliminary Design	6/14/05	3/22/06
16	Final Design	3/22/06	3/20/07
17	EMU I&T	1/24/07	6/5/07
18	Flight ICA Procure, Fab & Test	4/19/06	1/11/08
19	Flight Instrument Bay Piece-Part Fabrication & Assy	9/12/06	2/15/08
20	Flight 1 Integration & Test	2/19/08	6/16/08
21	Flight 1 Environmental Testing	6/17/08	10/6/08
22	Flight 1 Final Testing & PSR	10/7/08	12/16/08
23	**GMI Instrument Schedule Reserve**	**12/17/08**	**3/12/09**
24	Flight 1 Pack & Ship	3/13/09	3/19/09
25	GPM Spacecraft Integration & Test	4/1/09	9/1/09
26	GPM Observatory, Integ & Test, and Launch	9/2/09	12/14/10



GMI Level 2 Requirements

3.1.2.1 Minimum Set of Channels

The center frequencies and bandwidths of the GMI channel set shall include the nine channels identified in Table 3-1.

Table 3_1. Required GMI Channel Set and Performance

Chan nel #	Center Freq.[1] f_c [GHz]	CFS [MHz]	Pass-band Bandwidth[B [MHz] (Max.)	Pol.	Integration Time[2] [ms] (for reporting NEDT)	NEDT[2] [K] (Max)	Antenna 3 dB beam width[3] θ3dB [degrees] (Max.)
1	10.65	10	100	v	9.7	0.60	1.75
2	10.65	10	100	h	9.7	0.60	1.75
3	18.70	20	200	v	5.3	0.70	1.00
4	18.70	20	200	h	5.3	0.70	1.00
5	23.80	20	200	v	5.0	0.90	0.90
6	36.50	50	1000	v	5.0	0.55	0.90
7	36.50	50	1000	h	5.0	0.55	0.90
8	89.00	200	6000	v	2.2	0.70	0.40
9	89.00	200	6000	h	2.2	0.70	0.40

High Frequency Channels incorporated by Contract Modification

10	166.5	200	3000	v	2.2	1.9	0.40
11	166.5	200	3000	v	2.2	1.9	0.40
12	183.31	100	2x3500	v	2.2	1.9	0.40
13	183.31	100	2x4500	v	2.2	1.9	0.40

GMI Level 2 Requirements

4.2.2 GMI Interface Requirements

"Mechanical, electrical, and thermal interfaces, and environmental requirements and constraints between the GMI and the GPM Core Observatory shall be specified in the GPM Core Spacecraft Observatory to GMI Interface Control Document."

Instrument accommodation requirements were developed based upon extensive review, including:

- *Requirements for similar systems (see following chart)*
- *Instrument Concept and Risk Reduction Studies (ICRR) by 3 potential vendors*
- *Discussions with GPM Mission System Engineer and Observatory Manager*

GMI Level 3 Requirement

- *Mass allocation: 125 kg*
- *Power Allocation: 155 Watts*
- *Data Allocation: 35 kbps*
- *Specified stowed and deployed envelopes compatible with spacecraft and launch vehicle*

4.2.3 GMI Lifetime

"The GMI shall be designed to operate for 3 years, after a 60-day on-orbit checkout period. The high frequency channels, Channels 10 through 13, shall be designed for a minimum of 12 months of science measurements, after a 60-day on-orbit checkout period."

GMI Level 3 Requirement

GMI Technical Requirements,

Paragraph 3.1.1.2 On-Orbit Design Life

"The GMI shall be designed to operate on-orbit, within specification, for a minimum of 38 months…. The 38 months includes two months of on-orbit check-out followed by 36 months of science operation."

B.3.1.1.2 High Frequency Channel On-Orbit Design Life

The High Frequency Channels shall be designed to operate on-orbit, within specification, for a minimum of 14 months. This operational duration is referred to as design life. The 14 months includes two months of on-orbit checkout followed by 12 months of science operation. It is the goal of GPM to achieve the same design life for the High Frequency Channels as achieved by the GMI instrument (refer to instrument design life, requirement 3.1.1.2)

4.2.4 GMI Reliability

"The GMI shall meet all requirements with probability 0.87 over its operational lifetime. The high frequency channels, Channels 10 through 13 shall be designed for a reliability of 0.85 for their operational design life

GMI Level 3 Requirement

GMI Technical Requirements,

Paragraph 3.1.1.3 Probability of Success

"The GMI instrument shall have, as a minimum, an 87 percent probability of operation on-orbit, within specification, for the design life specified in 3.1.1.2."

B.3.1.1.3

"The Probability of Success for the High Frequency Channels shall have, as a minimum, an 85 percent probability of operation on-orbit, within specification, for the design life of the High Frequency Channels

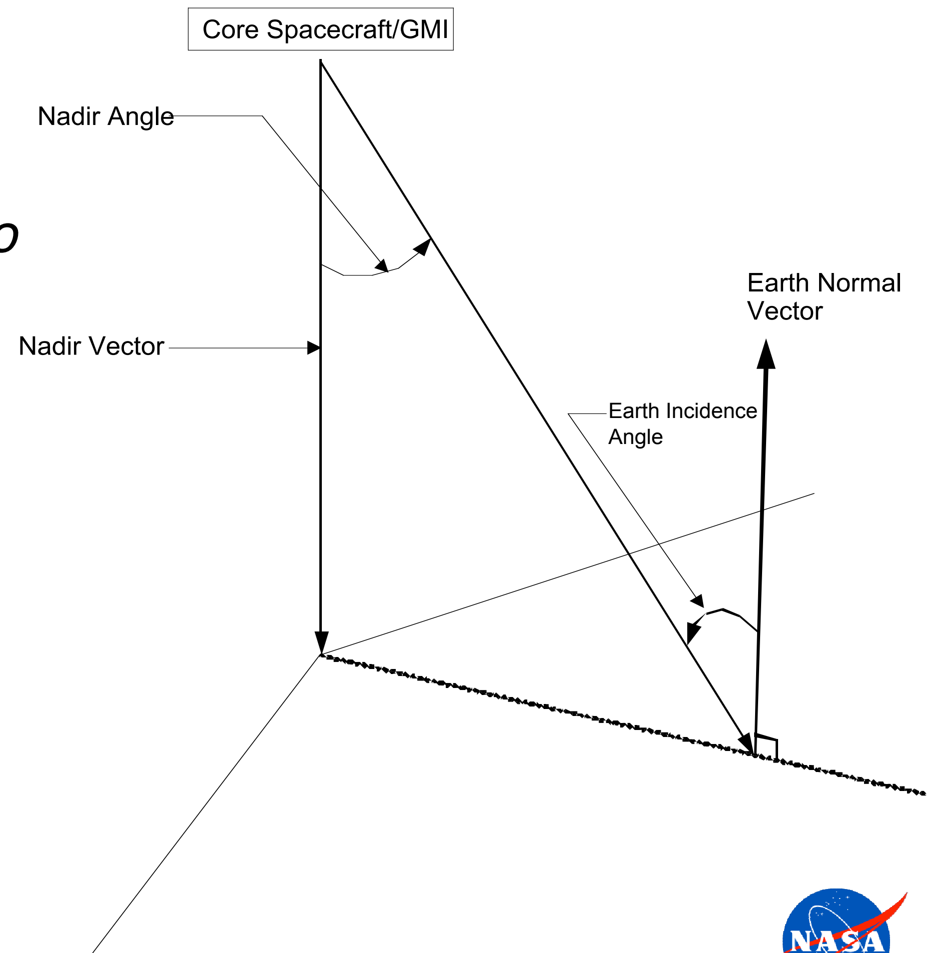
4.2.5 Earth Incidence Angle

"The GMI shall be designed to make measurements with an earth incidence angle of 52.8 degrees."

GMI Level 3 Requirement

GMI Technical Requirements, Paragraph 3.1.7.5.4.1

"The off-nadir angle…shall be set to a value between 48.3 and 48.7 degrees."



4.2.6 GMI Contiguous Coverage for Channels 1 through 7

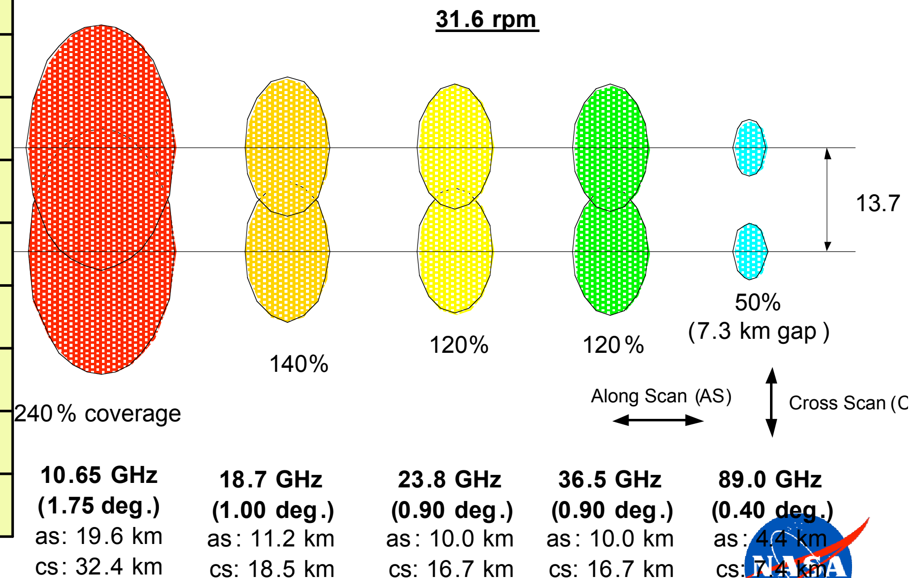
The GMI shall be designed such that its viewing parameters (i.e. the instantaneous field-of-view (IFOV), the earth incidence angle, and the scan rate) will provide contiguous spatial scene coverage from a altitude of 407 km for Channels 1 through 7. Contiguous coverage means that adjacent IFOV footprints, both scan-to-scan and within a scan, show positive overlap

GMI Level 3 Requirement

Table 3-1, Required GMI Channel Set and Performance, specified Antenna 3dB beam width

Channel #	Center Freq.[1] f_c [GHz]	CFS [MHz]	Pass-band Bandwidth[1].)	Pol.	Integration Time[2]	NEDT[2] [K] (	Antenna 3 dB beam width[3] θ_{3dB} [degrees] (Max.)
1	**10.65**	10	100	v	9.7	0.60	**1.75**
2	**10.65**	10	100	h	9.7	0.60	**1.75**
3	**18.70**	20	200	v	5.3	0.70	**1.00**
4	**18.70**	20	200	h	5.3	0.70	**1.00**
5	**23.80**	20	200	v	5.0	0.90	**0.90**
6	**36.50**	50	1000	v	5.0	0.40	**0.90**
7	**36.50**	50	1000	h	5.0	0.40	**0.90**
8	89.00	200	6000	v	2.2	0.70	0.40
9	89.00	200	6000	h	2.2	0.70	0.40

GMI Coverage Calculations
IFOVs from Requirements Document Beamwidths
Core Spacecraft
407 km Altitude, Ground Speed = 7.21 km/s



GPM Table 1, GMI vs TMI comparison

CH #	1,2	3,4	5	6,7	8,9	10-13
F(c), (GHz)	10.65 [1] 10.65 [2]	18.7 19.35	23.80 21.30	36.50 37.00	89.00 85.50	165.5-183.31 (+/-)A,B[4]
BW (MHz)	100 100	200 500	200 200	1000 2000	6000 3000	
Int. ti (ms)	9.7 29.6	5.3 14.8	5.0 14.8	2.2 7.4	2.2 3.7	2.2
NEdT (K)(per beam)	0.60 0.55 (0.97)	0.70 0.78 (2.06) [3]	0.90 0.89 (1.53)	0.55 0.77 (1.32)	0.70 1.12 (1.02)	1.9
IFOV $(km)^2$	19.6 x 32.4	11.2 x 18.5	10.0 x 16.7	10.7 x 16.7	4.4 x 7.3	4.4 x 7.3
	38.3 x 63.2	18.4 x 30.4	15.5 x 22.6	9.7 x 16.0	4.4 x 7.2	

Remarks: 1. nn.n=GMI, 2. nn.n=TMI, 3. (nn.n)=TMI scaled to GMI, 4. A= 3, B=9

GMI Level 2 Requirements

4.2.7 GMI Partial Coverage for Channels 8 through 13

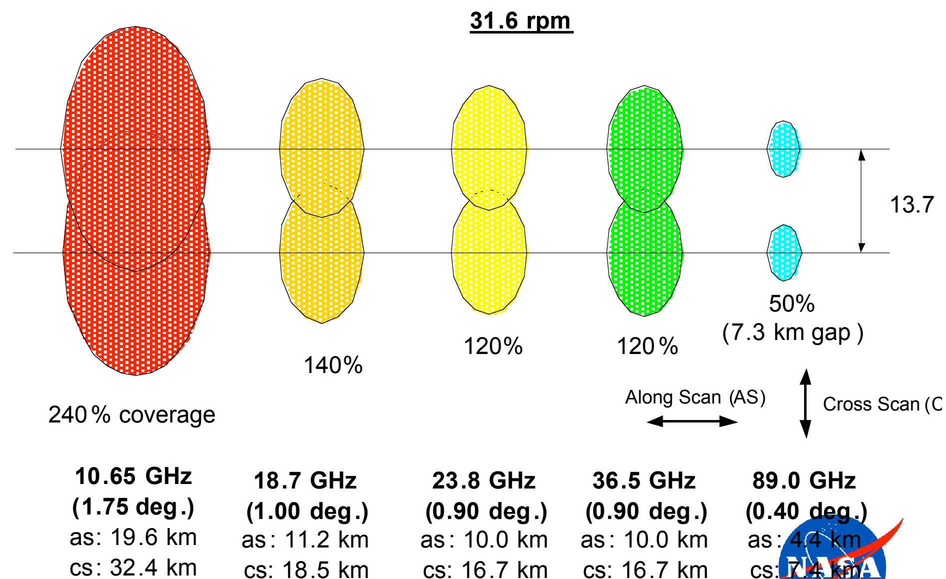
"The GMI shall be designed such that its viewing parameters will provide a minimum of 40% coverage of the spatial scene from scan-to-scan from an altitude of 407 km for Channels 8 through 13. Adjacent IFOV footprints within a scan shall show positive overlap

GMI Level 3 Requirement

Table 3-1, Required GMI Channel Set and Performance, specified Antenna 3dB beam width

Channel #	Center Freq.[1] f_c [GHz]	CFS [MHz]	Pass-band Bandwidth[1].)	Pol.	Integration Time[2]	NEDT[2] [K] (	Antenna 3 dB beam width[3] θ_{3dB} [degrees] (Max.)
1	10.65	10	100	v	9.7	0.60	1.75
2	10.65	10	100	h	9.7	0.60	1.75
3	18.70	20	200	v	5.3	0.70	1.00
4	18.70	20	200	h	5.3	0.70	1.00
5	23.80	20	200	v	5.0	0.90	0.90
6	36.50	50	1000	v	5.0	0.40	0.90
7	36.50	50	1000	h	5.0	0.40	0.90
8	89.00	200	6000	v	2.2	0.70	0.40
9	89.00	200	6000	h	2.2	0.70	0.40
10	166	200	4000	v	3.6	1.5	0.40
11	166	200	4000	v	3.6	1.5	0.40
12	183.3	100	3500	v/h	3.6	1.6	0.40
13	183.3	100	3500	v/h	3.6	1.5	0.40

GMI Coverage Calculations
IFOVs from Requirements Document Beamwidths
Core Spacecraft
407 km Altitude, Ground Speed = 7.21 km/s



4.2.8 GMI Resolution

"The GMI shall be designed such that IFOV resolution in the along-scan direction shall be less than or equal to 10 km when operating at an altitude of 407 km for Channels 6 through 9."

GMI Level 3 Requirement

Channel #	Center Freq.[1] f_c [GHz]	CFS [MHz] (Stab +/-) (Maximum Deviation)	Pass-band Bandwidth[1] B [MHz] (Max.)	Pol.	Integration Time[2] [ms] (for reporting NEDT)	NEDT[2] [K] (Max.)	Antenna 3 dB beam width[3] θ_{3dB} [degrees] (Max.)
1	10.65	10	100	v	9.7	0.60	1.75
2	10.65	10	100	h	9.7	0.60	1.75
3	18.70	20	200	v	5.3	0.70	1.00
4	18.70	20	200	h	5.3	0.70	1.00
5	23.80	20	200	v	5.0	0.90	0.90
6	36.50	50	1000	v	5.0	0.40	0.90
7	36.50	50	1000	h	5.0	0.40	0.90
8	89.00	200	6000	v	2.2	0.70	0.40
9	89.00	200	6000	h	2.2	0.70	0.40

Instantaneous Field of Views TMI vs. GMI

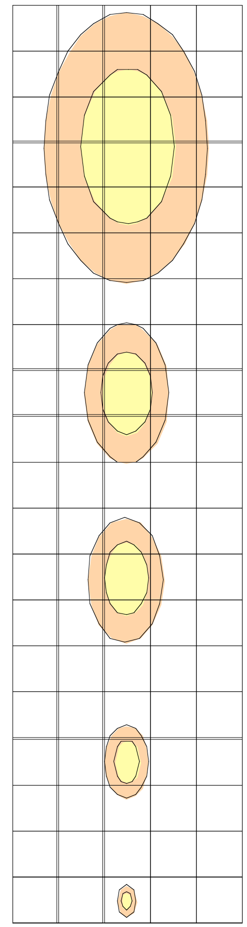
10.65 GHz
DT x CT (km)
TMI 59.0 x 35.7
GMI 33.8 x 20.5

18.7 GHz
DT x CT (km)
TMI 30.5 x 18.4
GMI 18.2 x 11.0

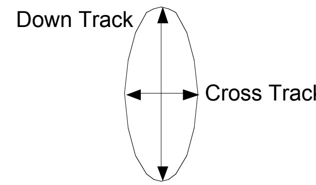
21.3 GHz
DT x CT (km)
TMI 27.2 x 16.5
GMI 16.0 x 9.70

37.0 GHz
DT x CT (km)
TMI 16.0 x 9.7
GMI 9.2 x 5.6

89.0 GHz
DT x CT (km)
TMI 6.7 x 4.1
GMI 3.8 x 2.3



10 km Grid



Notes:

TMI at 350 km,
Antenna Diameter = 0.61 m

GMI at 400 km
Antenna Diameter = 1.2 m

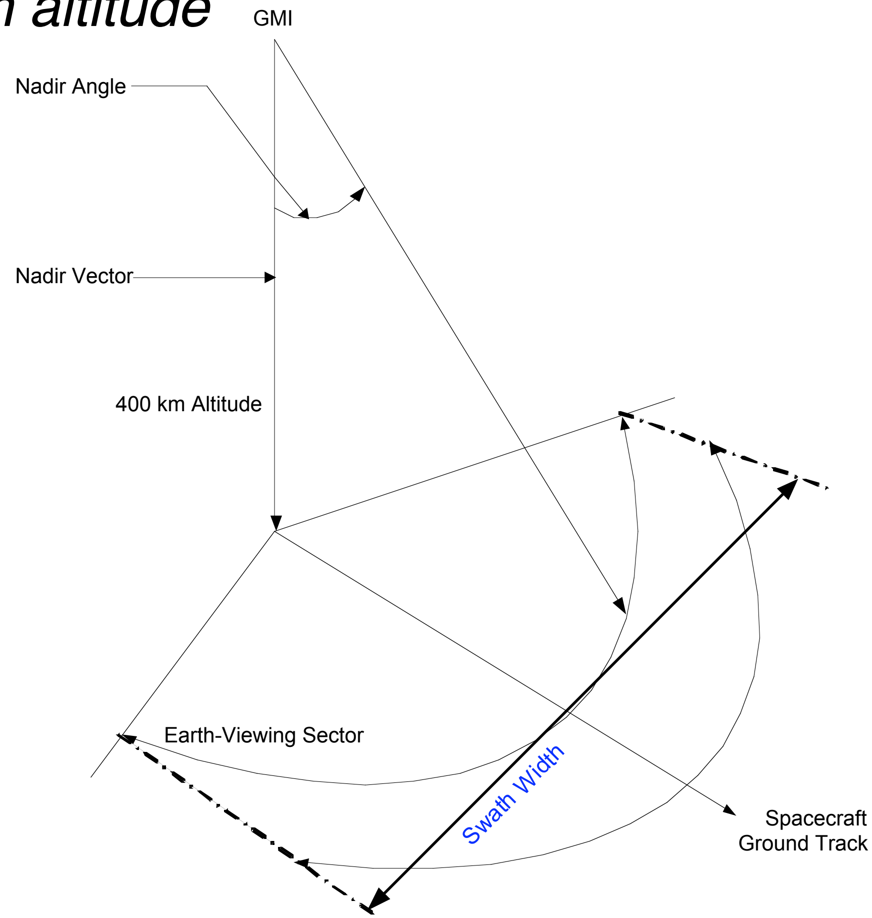
Earth Incidence Angle = 52.8 degrees

TMI 19.35 GHz, GMI 18.7 GHz

TMI 85.5 GHz, GMI 89.0 GHz

4.2.9 GMI Swath Width

"The GMI shall take scientific measurements over a swath width of 850 km when operating at 407 km altitude



GMI Level 3 Requirement

GMI Technical Requirements, Paragraph 3.1.7.2.1, Earth Viewing Sector Size

"The Earth-viewing sector shall provide a minimum of 130 degrees and a maximum of 145 degrees continuous viewing arc."

- *Swath width is a design characteristic of the instrument*
- *A spacecraft altitude of 400 km, an Earth Incidence angle of 52.8 °, and a scan sector of 130° provides the required swath width*

4.2.10 GMI Data Allocation

The GMI shall deliver no more than 34 kbps of continuous science data to the spacecraft bus, with no more than an additional 1 kbps of housekeeping data

GMI Level 3 Requirement

B.4.1.3.4 Science Data Telemetry Rate

- *In the GMI Operational Mode, the GMI shall produce an orbital average science data rate not to exceed 24 kbps plus , as appropriate, an additional [TBD] kbps for Channels 10 through 13 that will be added following contract award/modification*

- *10 kbps additional data allocation was provided for the High Frequency Channels*

GMI Level 2 Requirements

4.2.11 Error Characterization of Level 1 Brightness Temperature Products – Channels 1 through 9

For channels 1 through 9, the brightness temperature data of the GMI scene, i.e. antenna main lobe, shall be characterized by uncertainties less than 1.5 K per sample based on samples representing beam movement through one IFOV

Instrument calibration provides the basis for Error characterization

GMI Level 3 Requirement

The GMI will develop a well calibrated instrument that incorporates the following calibration features:

- ***Hot and cold calibrated measurements each scan***
- ***Hot load carefully designed to minimize thermal gradients both spatially and temporarily***
- ***Multiple temperature sensors on hot load to ensure good characterization***
- ***Four-point calibration***

GMI Level 2 Requirements

4.2.12 Error Characterization of Level 1 Brightness Temperature Products – Channels 10 through 13

For channels 10 through 13, the brightness temperature data of the GMI scene, i.e. antenna main lobe, shall be characterized by uncertainties less than 2.0 K per sample based on samples representing beam movement through one IFOV

Instrument calibration provides the basis for Error characterization

GMI Level 3 Requirement

The GMI will develop a well calibrated instrument that incorporates the following calibration features:

- ***Hot and cold calibrated measurements each scan***
- ***Hot load carefully designed to minimize thermal gradients both spatially and temporarily***
- ***Multiple temperature sensors on hot load to ensure good characterization***
- ***Four-point calibration***

GMI Design: Resource Estimates / Margin

	Current Best Estimate	Allocation	Margin (Alloc. – CBE) / Alloc.
Mass [kg]	111	125*	11%*
Power [W] (orbital average)	122	155*	21%*
Data Rate [kbps]	25	35	29%

Allocation values include new mass and power resource allocations for high frequency channels and Ball instrument mounting concept. These allocations are presently in negotiation with Ball

Risk

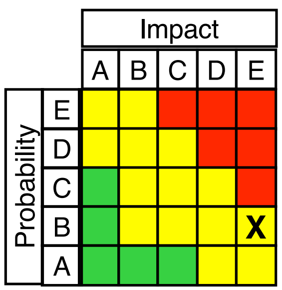
Risk H-16: DPR/GMI Interference

Risk Statement: Given that GPM will carry two instruments that maintain only a small separation in operating frequencies (KaPR radar transmits at 35.55 GHz and GMI Channels 6 and 7 will take measurements in the 36.0GHz to 37.0GHz range) and the instruments are within close physical proximity to one another; there is potential for Radio Frequency Interference (RFI) resulting in performance degradation of GMI. If interference is discovered at observatory-level integration and testing, GPM could suffer significant delays while a technical fix is found.

Work performed by the potential GMI vendors during the Instrument Concept and Risk Reduction (ICRR) studies addressed the possible instrument interference. However, the data was inconclusive with the three vendors' results differing greatly. Addressing this issue in GMI design was a consideration in the GMI procurement selection.

Risk Data:

Level: Mission



Owner: Steve Bidwell

Timeframe: Long-Term

Mitigation: To avoid the possibility of late discovery of a radar / radiometer interference, it is suggested that the GMI contractor provide early testing and / or detailed analysis increasing the level of confidence in result. At observatory-level integration and testing, a comprehensive energized radar and radiometer demonstration will be performed to conclusively determine whether interference exists.

Contingency:

Risk H-17: GMI Cold Calibration Field of View

Risk Statement: Given that the current volume envelopes for the GPM spacecraft limit the positioning options for both the solar arrays and the GMI instrument; it is possible that the deployed solar arrays will interfere with GMI's cold calibration field of view (FOV).

Risk Data:

Level: Element (GMI)

Probability	Impact: A	B	C	D	E
E					
D					
C					
B				X	
A					

Owner: Steve Bidwell

Timeframe: Short-Term

Mitigation: Provide the spacecraft vendor with the cold-sky field-of-view, volume referenced to the GMI coordinate system, so that they may model and accommodate the FOV in the spacecraft design.

Contingency: Ball's concept for antenna side stowage may enable the instrument mounting deck to be raised. Raising the mounting deck alleviates the view over the solar array but, conversely, the spacecraft communication antenna field-of-view must be considered for interference with the GMI antenna.

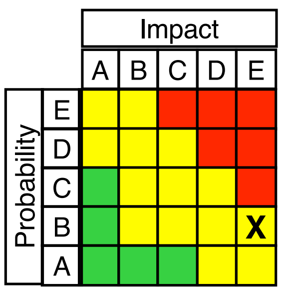
The shape and orientation of the cold sky reflector may be altered to affect a more zenith pointing field-of-view.

Shape the solar array panel (on +Y side of spacecraft) to allow cold sky field-of-view.

Risk H-18: GMI Spin Drive Mechanism

Risk Statement: Given that Ball's baseline design for the GMI instrument includes use of an in-house built spin drive mechanism, the same one that failed on WindSat Coriolis (the cause is under investigation); it is possible that it will fail on GPM also, rendering the instrument useless.

Risk Data:
Level: Element (GMI)



Owner: Steve Bidwell
Timeframe: Short-Term

Mitigation: Continue keeping abreast of the results of the WindSat analysis. Continue conversations with Ball to determine how they intend to mitigate the risk.
Ball is conducting a make/buy decision on the BAPTA.

Contingency:
Windsat slip ring design was chosen for its high frequency noise characteristics. Investigate whether GMI has similar requirements on slip ring noise. Other types of slip ring designs may be possible, such as composite type brushes as used on SSM/I and TMI programs.
Investigate the proposed GMI position resolver technique and its susceptibility to slip ring noise.
Employ selective redundancy for resolver circuitry.
Ensure that Ball is kept informed of NRL / WindSat lessons learned.

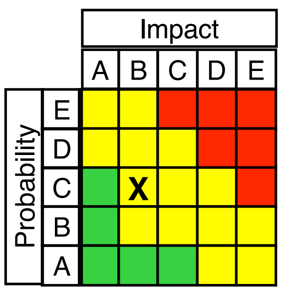
Risk H-19: GMI's 36.5 GHz NEΔT

Risk Statement: Given that the NEΔT requirement at 36.5 GHz is 0.4K and that Ball's initial analysis indicates they can achieve that value with front-end filtering but that there is no margin in the 0.4K requirement at inception of the contract; it is possible that they might not be able to achieve the required value.

The KaPR transmits at 35.55 GHz and in order to mitigate risk R-8, GMI/DPR interference, Ball has added extensive front-end filtering to the GMI instrument, which transmits at 36.5 GHz. Ball's analysis indicates the filtering is sufficient to eliminate interference but no margin remains for the 0.4K requirement.

Risk Data:

Level: Element (GMI)



Owner: Steve Bidwell

Timeframe: Long-Term

Mitigation: Work closely with Ball to ensure that their mitigation strategy is effective. Request/receive accurate DPR data from JAXA to validate Ball's analysis. If the RFI flux is less than the values used in the current analysis, Ball may be able to reduce the filtering, thereby reducing the noise and increasing the requirement margin.

Contingency: Pursue discussion with Ball build on potential for several types of filters which can be used interchangeably, based on results of the RFI analysis.

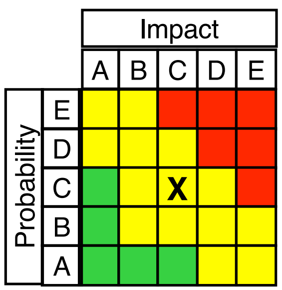
Keep science team informed of this risk. NEDT performance impact is best assessed by science team.

Risk H-20: GMI Power Margin

<u>Risk Statement</u>: Given that Ball's current (July 2005) power margin is only 12% and it should be $\geq$15% at PDR; it is possible that the power growth associated with program maturity could exceed the power budget and require redesign late in the program with impacts to schedule and/or cost.

<u>Risk Data</u>:

Level: Element (GMI)



Owner: Steve Bidwell

Timeframe: Long-Term

<u>Mitigation</u>: Watch Ball's evaluation of their risk and the trade studies they have identified to attempt to reduce power and increase power margin.

<u>Contingency</u>: Assess power margin held at mission systems level for potential of relaxing GMI power allocation. Power allocation should not be allowed to drive cost, schedule, and technical risks to the GMI, if relaxation is possible.

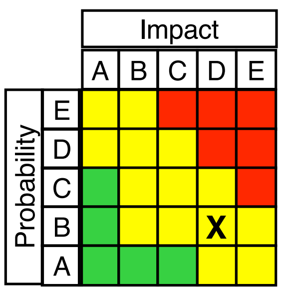
Risk H-21: GMI Gunn Diode Oscillators

Risk Statement: Given that space qualified Gunn diode oscillators (GDO) are no longer being produced and that BATC plans to use GDOs in the GMI instrument; it is possible that an inadequate number of the approximately 105 Millitech owned existing GDOs will meet BATC's requirements, resulting in a technical and schedule impact if the alternative solution is implemented.

GDOs are the conventional approach for providing the local oscillator signal to heterodyne receivers. Ball's design includes one GDO for the 89 GHz channels and two for the high frequency millimeter-wave channels. Millitech's existing GDOs were produced in three different lots and were purchased from a supplier that is no longer in business. BATC prefers to use GDOs due to their flight heritage and lower power consumption (see GMI Power Margin Risk, H-35) when compared to the alternative, which is dielectric resonant oscillators (DRO) combined with frequency multipliers and amplification. The DRO approach has not been completely evaluated and there may be some unknown risks associated with it.

Risk Data:

Level: Element (GMI)



Owner: Steve Bidwell

Timeframe: Short-Term

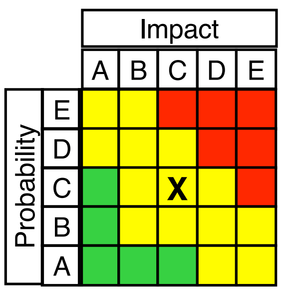
Mitigation: BATC has contracted with Millitech to perform a pre-screening program measuring thermal rise, a good predictor for failures. The pre-screen should last 1-2 months, followed by screening which will take an additional 1-2 months.

Contingency: Keep abreast of the DRO program for CMIS and ATMS and use the knowledge gained in that program to implement DRO usage for GMI. Work closely with BATC to determine and resolve any increased power requirements for implementing the DRO solution.

Risk H-22: GMI Cost Growth

Risk Statement: If additional staffing and subcontract costs increase (due to primarily higher overhead rates); then the funding requirements for the GMI contract may increase, impacting the funding reserves held by the GPM Project

Risk Data:
Level: Mission



Owner: Mark Flaming
Timeframe: Mid-Term

Mitigation: Lien $4 million of the Project Reserve to be held as contingency.

Contingency:

GLOBAL PRECIPITATION MEASUREMENT

Day 1 - December 6, 2005
Location: NASA GSFC B16W-N76/80

Time	Section	Event	Presenter
8:30 AM		Logistics & Announcements	Durning
8:35 AM	1	Introduction	Durning/Ho
8:45 AM		Charge to Review Team/RIDs: Purpose & Review Criteria	Ho
8:55 AM		HQ Overview	Neeck
9:10 AM	2	GPM Mission Overview	Durning
9:55 AM	3	Science Requirements	Hou
10:25 AM		**Break**	
10:40 AM	4	Mission Requirements	Bundas
11:10 AM	5	Mission Architecture	Bundas
11:55 AM		**Lunch**	
12:55 PM	6	Systems Engineering Processes	Bundas
1:40 PM	7	System Safety and Mission Assurance	Toutsi
1:55 PM	8	External Interfaces	Hwang
2:10 PM	9	Dual Precipitation Radar (DPR) Overview/Requirements	Woodall
2:55 PM		**Break**	
3:10 PM	10	GPM Microwave Imager (GMI) Overview/Requirements	Flaming/Bidwell
4:10 PM	11	H-IIA Launch Vehicle	Woodall
4:30 PM		Review Team Caucus	
4:40 PM		**End of Day 1**	